

The pearl oyster *Pinctada imbricata radiata* (Leach, 1814) (Bivalvia: Pteriidae) reaches Minorca, Balearic Islands

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We report on the presence of the pearl oyster *Pinctada imbricata radiata* (Leach, 1814) in two sheltered areas of the island of Minorca, Maó Harbour and Fornells Bay. Shallow depths (0-1.5 m) have been surveyed by free diving. Living oysters have been found in only 4 of the 22 surveyed sites, with densities ranging between 2.12 oysters·100 m⁻² and 0.12 oysters·100 m⁻², which indicates that the species is currently non-invasive. Average shell length in the observed specimens was 60.2 ± 13.9 mm (mean ± SD). According to the size of the oldest specimen found and the reports of a shellfish farmer from the Maó Harbour, date of introduction should be around year 2016. Since the introduction is recent, attention must be paid to the future spread of this species, regarding its high invasive capacity in several Eastern Mediterranean localities.

Keywords: Pearl oyster; *Pinctada radiata*; alien species; Minorca; Balearic Islands; Mediterranean Sea.

L'OSTRA PERLÍFERA *PINCTADA IMBRICATA RADIATA* (LEACH, 1814) (BIVALVIA: PTERIIDAE) ARRIBA A MENORCA, ILLES BALEARS. Es dona a conèixer la presència de l'ostra perlífera *Pinctada imbricata radiata* (Leach, 1814) a dues badies de la costa de Menorca, el port de Maó i la badia de Fornells. S'han prospectat en apnea fons somers situats entre 0 i 1,5 m i s'han trobat ostres vives a 4 de les 22 estacions prospectades, amb densitats d'entre 2.12 ostres·100 m⁻² i 0.12 ostres·100 m⁻², lluny de densitats que podrien atribuir-se a una espècie invasora. La llargada mitjana de les ostres capturades ha estat de 60.2 ± 13.9 mm (mitjana ± DS). En funció de la mida de l'individu més gran observat i a la informació proporcionada per un mariscador del port de Maó, la data d'introducció ha de situar-se al voltant de l'any 2016. Com la introducció és recent, s'ha de vigilar la possible futura expansió d'aquesta espècie ja que té un elevat potencial invasor en diverses localitats de la Mediterrània Oriental.

Paraules clau: ostra perlífera; *Pinctada radiata*; espècie introduïda; Menorca; illes Balears; Mediterrània.

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Introduction

Introduction of alien species is one of the main threats to the maintenance of biodiversity in ecosystems and a serious menace for their correct functioning when they become invasive (Elton, 1958; Mack *et al.*, 2000). Alien species are also threatening several coastal habitats around the world (Ruiz *et al.*, 1997, 1999; Molnar *et al.*, 2008), the Mediterranean Sea being a hot spot for both introduced and invasive species (Galil, 2000; Boudouresque and Verlaque, 2002; Zenetos *et al.*, 2010, 2012).

A huge part of the aliens that have become established in the Mediterranean Sea are lessepsian species, i.e. species that have entered the Mediterranean Sea through the Suez Canal (Por, 1978). They have become very common in the Eastern Mediterranean, primarily along the Levantine coasts, where they have displaced most native species and have largely impacted coastal ecosystems (Galil, 2007; Sala *et al.*, 2011; Verges *et al.*, 2014; Rilov *et al.*, 2018). However, only few lessepsian species have reached the western Mediterranean and even less have arrived to its north-western part (Zenetos *et al.*, 2012; Galil *et al.*, 2018). However, occasional reports of lessepsian species are increasing in the north-western Mediterranean, such as those of the cornet-fish, *Fistularia commersonii* Rüppell, 1838 (Sánchez-Tocino *et al.*, 2007; García *et al.*, 2016), the ctenophore *Mnemiopsis leidyi* Agassiz, 1865 (Fuentes *et al.*, 2010), the small bivalve *Fulvia fragilis* (Forsskal in Niebuhr, 1775) (López-Soriano *et al.*, 2009), the pearl oyster *Pinctada imbricata radiata* (Leach, 1814) (Altimira, 1977; López-Soriano and Quiñonero-Salgado,

2019) or the sea slug *Bursatella leachii* Blainville, 1817 (Oliver and Terrasa, 2004; Weitzmann *et al.*, 2007). Here we give the first quantitative data on the presence of a lessepsian species, the pearl oyster *Pinctada imbricata radiata* (from now on *Pinctada radiata*) in sheltered areas of Minorca (Balearic Islands, north-western Mediterranean), and discuss several aspects of its introduction such as date of colonization, individual size, densities and current habitat preferences.

Materials and Methods

A recently dead individual of *Pinctada radiata* was found in Fornells Bay, Minorca (40° 2' 58.9''N; 4° 8' 21.1''E), at a depth of 6 meters on August 26th, 2020, during a biological survey in a dismantled aquaculture farm. A field mission was lately performed between October 26th and October 28th covering several sites across the bays of Fornells and Addaia and inside Maó Harbour (Fig. 1) to find out the current distribution of *Pinctada radiata* in the main sheltered areas of Minorca.

Transects of varying lengths were performed at each site by a free diver (Table 1). One meter-wide transects were made parallel to shore at depths ranging from 0.2 to 1.5 m depth, except in station 2 where four transects of 100 m long forming a cross were surveyed. The beginning and end of each transect were positioned with GPS and the itinerary was plotted into a GIS system. Total covered distance was obtained using GIS tools. Surveys were performed on primary rock, seagrass meadows, artificial hard substrates (docks), boulder/rubble fields and detritic bottoms.

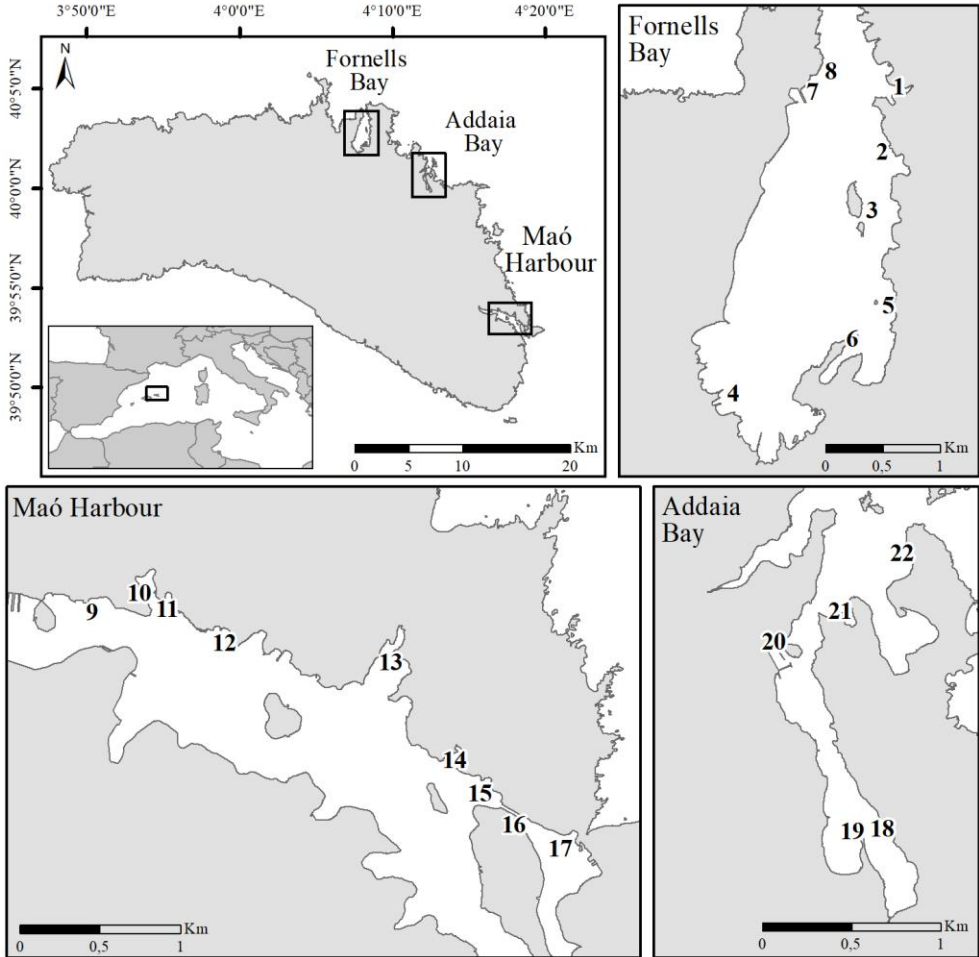


Fig. 1. Sampled localities and sites. Numbers correspond to sites reported in Table 1.

Fig. 1. Localitats i estacions mostrejades. La numeració correspon a les estacions que figuren a la taula 1.

Completely sandy and muddy environments were avoided. Divers annotated the number of alive individuals and dead shells along each transect, collecting the alive individuals for later measurements in the laboratory. Three measures were taken for each individual: hinge length, shell length and shell height (Tlig-Zouari *et al.*, 2010; Lodola *et al.*, 2013). Measurements were obtained with a

calliper with a resolution of 0.1 mm. Manuel Cabrera, shellfish farmer from Maó harbour, was interviewed in October 27th to obtain qualitative data on the introduction. Antoni M. Grau has provided unpublished information on the presence of *Pinctada radiata* in Mallorca.

Table 1. Surveyed localities, transect lengths, number of living and dead specimens found along the transects and density of living specimens.**Taula 1.** Localitats prospectades, longitud dels transsectes, nombre d'individus vius i morts observats en cada transsecte i densitats d'individus vius.

Site	Locality	Site name	Transect length (m)	Alive/Dead	Density (ind·100 m ⁻²)
1	Fornells	Cabra Salada	764	0/0	
2	Fornells	Aquaculture facility	400	0/4	
3	Fornells	Illa Sargantana	802	1/0	0.12
4	Fornells	Moll d'en Miami	83	0/0	
5	Fornells	Illa des Porros	104	0/0	
6	Fornells	Escull des Cagaires	459	0/0	
7	Fornells	Moll de Tramuntana	355	0/0	
8	Fornells	Castell Sant Antoni	165	0/0	
9	Maó	Es Riu Pla	519	11/15	2.12
10	Maó	Cala Rata	109	0/0	
11	Maó	Cala Ratolí	206	4/1	1.94
12	Maó	Cala Sant Antoni	491	6/2	1.22
13	Maó	Cala Llonga	453	0/0	
14	Maó	Cala Lladró	317	0/1	
15	Maó	En Cremat	439	0/1	
16	Maó	Canal d'Alfons XIII	156	0/0	
17	Maó	Cala Teulera	771	0/1	
18	Addaia	Moll de Montgofre	92	0/0	
19	Addaia	S'Era	436	0/0	
20	Addaia	Illa de Ses Mones	150	0/0	
21	Addaia	Cala Roja	215	0/0	
22	Addaia	S'Estany	424	0/0	

Results

According to Manuel Cabrera first adult individuals of *Pinctada radiata* were observed at the inner part of Maó harbour (station 9; Fig. 1) in 2017, whether attached to stones and dead bivalve shells or in artificial hard substrates like docks and metallic or plastic structures used in shellfish farming. No density measures were performed at that time but according to the perception of the farmer, *Pinctada* abundance has increased during the last three years. The distribution at the inner part of the Maó Harbour is mainly restricted to the upper infralittoral zone (0

to 1.5 m) although occasional individuals have been observed down to 8 m depth.

Dead shells were found in 7 of the 22 surveyed sites, while living specimens were observed only in 4 sites, 3 in Maó Harbour and 1 in Fornells Bay (Table 1; Fig. 2). Densities ranged between 2.12 and 1.22 oysters·100 m⁻² in Maó Harbour and 0.12 oysters·100 m⁻² in Fornells Bay (Table 1). A total of 37 pearl oysters were collected and measured. Average hinge length of the collected oysters was 56.7 ± 8.9 mm, average shell length was 60.2 ± 13.9 mm and shell height was 59.6 ± 12.1 mm (mean \pm SD). Maximum shell length was 94 mm in a specimen collected at station 9.

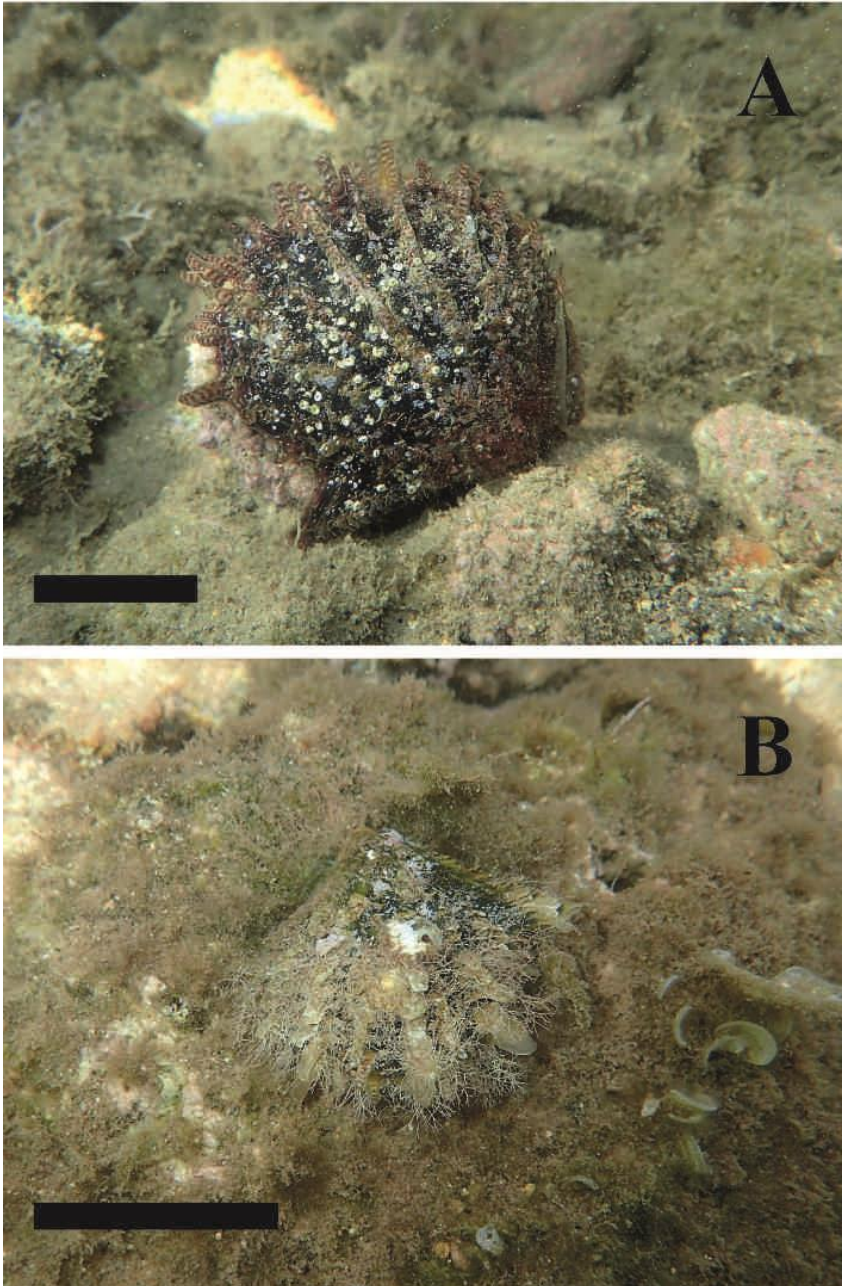


Fig. 2. *In situ* habit of living specimens in Maó Harbour (A) and Fornells Bay (B). Bar length = 3 cm.
Fig. 2. Aspecte in situ d'individus vius al port de Maó (A) i a la badia de Fornells (B). Longitud de la barra = 3 cm.

Discussion

Pinctada radiata was probably the first lessepsian species that entered the Mediterranean as soon as 1874, reported from Alexandria (Monterosato, 1878). The species was also reported shortly afterwards from the Gulf of Gabès, Tunisia (Bouchon-Brandely and Berthoule, 1891; Dautzenberg, 1895) which means a fast dispersion across the south-eastern Mediterranean coasts; however, it abruptly stopped its progression towards the western basin (Antit *et al.*, 2011). The species has extended its distribution to most of the Eastern and Central Mediterranean (Monterosato, 1899; Pallary, 1912; Serbetis, 1963; Barash and Danin, 1973; Sabelli, 1969; Kinzelbach, 1985; Tlig-Zouari and Zouali, 1994; Galil, 2000; Galil and Zenetos, 2002; Gofas and Zenetos, 2003; Pancucci-Papadopoulou *et al.*, 2005; Bitar, 2014; Evagelopoulos *et al.*, 2015; Evans *et al.*, 2015) and southern and middle Adriatic Sea (Dogan and Nerlović, 2008; Petović and Mačić, 2017; Gavrilović *et al.*, 2017; Petović, 2018).

Records in the western Mediterranean usually refer to a single or very few specimens like in central Catalonia (Altimira, 1977), Mallorca (Pons-Moyà and Pons, 2001), Sardinia (Stasolla *et al.*, 2014), Corsica (Boudouresque, 1999), Liguria (Garavelli and Melone, 1967), Sicily (Di Natale, 1982; Gaglini, 1984; Mannino *et al.*, 2016) and the Calabrian shores of the Straits of Messina (Crocetta *et al.*, 2009; Giacobbe and Renda 2018a,b). According to Antoni M. Grau (pers. comm.) the species has been collected in Palma Bay around year 2012 and small shells are rather common in Port d'Andratx from 2010. The only quantitative data available is provided by López Soriano and Quiñonero-Salgado (2019) who reported 22

living specimens attached to mussel ropes in Ebro Delta (southern Catalonia), suggesting the presence of an established population in this area. Thus, the present population in the Maó Harbour represents the second well-established population in the western Mediterranean.

Dispersion occurs both by anthropogenic activities such as shellfish farming or shipping (Bellaaj-Zouari *et al.*, 2012; Theodorou *et al.*, 2019) or naturally by sexual reproduction (Tlig-Zouari *et al.*, 2009; Lodola *et al.*, 2013). In fact, the pelagic larval phase of *Pinctada* lasts for three weeks (Gervis and Sims, 1992), conferring to this species a high potential for dispersal. *Pinctada* has likely been introduced in the inner part of the Maó Harbour by shellfish farming, although secondary dispersion by larval dispersal probably accounts for the presence in the outer Maó Harbour and Fornells Bay.

The observed shell dimensions of the specimens collected in Minorca are similar to those collected in Tunisia (ranging from 33.6 and 72.7 mm depending on the localities; Seurat, 1929; Tlig-Zouari and Zaouali, 1998; Tlig-Zouari *et al.*, 2009, 2010; Bellaaj-Zouari *et al.*, 2012) and the Persian Gulf (39 to 77 mm; Al-Mafda *et al.*, 1998). The maximum value of 94 mm equals the biggest recorded in the Red Sea (93.2 mm; Yassien *et al.*, 2009). Curiously, specimens collected in the Egyptian Mediterranean and in Malta are smaller (Yassien *et al.*, 2000; Deidun *et al.*, 2014). Given the very big size of at least one specimen found in station 9 and that the life span of *Pinctada radiata* is of 5 years (Yassien *et al.*, 2009), the date of its possible introduction in Maó Harbour points to year 2016, one year before pearl oysters were first observed by shellfish farmers.

Oyster beds of *Pinctada radiata* reach densities of 164 shells m⁻² in Gimsha Bay (Red Sea) (Yassien *et al.*, 2009) and 16 to 59 shells m⁻² in different beds of the Persian Gulf (Jahangard and Rustaian, 1995), although in other areas densities do not exceed 1 shell m⁻² (Movahedi-Nia *et al.*, 2015). Preferred habitats for *Pinctada radiata* in its native distribution range are seagrass and algal beds, while sandy areas host lower oyster densities. Even that, oysters can be extremely abundant in sandy areas, with densities of up to 95 shells m⁻² (Yassien *et al.*, 2009). In their native range oysters can be so abundant that are considered ecosystem engineers, but oyster populations are declining in certain areas due to excessive trap fishing (Al-Maslami *et al.*, 2018). In invaded areas from the Gulf of Gabès (Tunisia) *Pinctada radiata* can reach densities of up to 145 shells m⁻² (Derbali *et al.*, 2011; Tlig-Zouari *et al.* 2009), although values of 0 to 0.3 individuals m⁻² are also common outside oyster beds (Derbali *et al.*, 2011; Tlig-Zouari *et al.*, 2009, 2010). Densities in Minorca are several orders of magnitude lower, which means that the environmental setting is not very suitable for the species or/and that the introduction is so recent that invasion has just started. In fact, the future spread of *Pinctada radiata* in Minorca is unknown as oceanographic conditions are very different from those found in the Red Sea, the Persian Gulf or other eastern Mediterranean areas where the species has become invasive.

Habitat preferences are another interesting point. In the Red Sea *Pinctada radiata* is very abundant in seagrass meadows and algal (*Sargassum*)-covered beds and frequently grows in tight clusters built by a matrix of dead shells (Yassien *et al.*, 2009). In the Gulf of Gabès (Tunisia) high population densities are associated

with large cover of seagrass *Posidonia oceanica* (Linnaeus) Delile, whose rhizomes provide an excellent substratum for attachment (Derbali *et al.*, 2011). *Pinctada* is also very abundant in *Cymodocea nodosa* (Ucria) Ascherson meadows. It grows abundantly on rocks (Tlig-Zouari *et al.*, 2009), but also appears in muddy bottoms (Boudaya *et al.*, 2019). In Minorca most of the specimens were found growing on rocks or rubble areas and the only specimens found in seagrass meadows were in fact growing over an artificial substrate placed inside the meadows (station 2).

Regarding depth preferences, populations in Gimsha Bay (Red Sea) mainly grow between 4 and 6 m (Yassien *et al.*, 2009). In the Gulf of Gabès (Tunisia) *Pinctada radiata* was found between the littoral zone down to 100 m depth, with highest population densities recorded between 2 and 20 m depth (Derbali *et al.*, 2011). These observations contrast with ours in Minorca, where most of the specimens were found above 1.5 m depth. Deeper surveys have to be performed in Minorca in order to find out the real depth range of this species.

The distribution of *Pinctada radiata* in Minorca seems now to be restricted to Maó Harbour and Fornells Bay since it has not been reported in the several surveys that are being regularly performed in open sea environments (Marsinyach *et al.*, in press). The relative abundance in the degraded environments of the inner part of the Maó Harbour can be explained by its ability to withstand moderate pollution levels (Al-Mafda *et al.*, 1998; Macfarlane *et al.*, 2006; Gifford *et al.*, 2006; Tempesti *et al.*, 2020) and its wide salinity tolerance (Moussa, 2018), but probably also because an increased abundance of phytoplankton (Puigserver and Moyà, 2000) and

particulate organic matter (POM) fosters the growth of suspension-feeders in Maó Harbour. The settlement of new populations in open sea areas from Minorca is unknown, although the low POM and chlorophyll concentrations regularly found in open waters (Fernández de Puelles *et al.*, 2001; García-Martínez *et al.*, 2019) will probably suppose a strong barrier for its widespread colonization.

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